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HANDBOOK OF GAME THEORY AND INDUSTRIAL ORGANIZATION: AN INTRODUCTION

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ABSTRACT. We introduce here the volume *Handbook of Game Theory and Industrial Organization*, by L. C. Corchón and M. A. Marini (ed.), Edward Elgar, Cheltenham, UK and Northampton, MA, by describing its main aim and its basic structure.

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JEL codes: C02, C50, C70, C71, C72, C73, C78, C79, D21, D43.

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Game theory lies at the heart of modern industrial organization. Over the second half of the last century, it provided a sound foundation to the main equilibrium concepts adopted in classical industrial economics, as in Cournot, Bertrand and Stackelberg models. It also allowed to build up new and rigorous conceptual frameworks for many industrial organization topics, as product differentiation, predation, delegation, mergers, collusion and R&D in imperfectly competitive markets. Finally, and perhaps most importantly, over the years game theory has constantly continued to inspire new research grounds in the field of industrial organization which, in some cases, went far beyond the scope of the discipline. This occurred, for instance, in the development of dynamic and incomplete information games or in the recent applications of game theory to law and economics, networks, digital economy, auctions, experiments, health economics, intellectual property rights, contests and corruption, just to cite a few. Furthermore, it should be stressed that the relationship between game theory and industrial organization has never been unidirectional.¹

Thus, it is not exaggerated to say that game theory has become the common language of industrial organization.² In particular the adoption of a sound mathematical language has allowed industrial organization to steadily progress towards new and unexplored fields. As an example, the recent use of experimental game theory for industrial economics has opened the door to behavioral models for the explanation of the bias of consumers and sellers in the market.³

Due to the increasing interlink between game theory and industrial organization, the current volume aims to provide a solid introduction to the main topics lying at the crossroads between these two disciplines. In managing such a - seemingly arduous - task, our major contribution as editors was mainly to attract an impressive array of renown economists in the challenge to yield up-to-date surveys for the volume. As a final result, and specially thanks to the outstanding quality of the contributors, the current *Handbook* appears suitable to both established researchers as well as to graduate and advanced undergraduate students.

Given the wide heterogeneity of topics being at the boundary between game theory and industrial organization, our primary task in assembling the volume was to give a rational structure to the great amount of material gathered for its preparation.

In our final plan for the *Handbook* we judged as appropriate to divide the volume in five subsets of distinct topics: (i) *Basic games in industrial organization*; (ii) *Dynamic games in industrial organization*; (iii) *Information and search*; (iv) *Collusion and mergers*; (v) *Special topics*.

More specifically, part I of the *Handbook* aims at providing an overview of the basic game-theoretic tools currently used in modern industrial organization, as lattice techniques, aggregative games, monopolistic competition models, oligopoly models with product differentiation, welfare analysis and contest theory.

¹As observed by Bagwell and Wolinsky (2002): "First, the needs of industrial organization fed back and exerted a general influence on the agenda of game theory. Second, specific ideas that grew out of problems in industrial organization gained independent importance as game theoretic topics in their own right. Third, it is mostly through industrial organization that game theory was brought on large scale into economics and achieved its current standing as a fundamental branch of economic theory." (Bagwell and Wolinsky, 2002, p.1852).

²This is confirmed, if ever needed, by Fudenberg and Tirole's long survey contained in the *Handbook of Industrial Economics* (1989) actually encompassing most of the relevant topics in noncooperative game theory.

³See the survey on "Experimental Industrial Organization" by Brandts and Potters in this *Handbook*.

Part II introduces the state of the art in the literature applying dynamic games to well-known dynamic industrial organization issues as Stackelberg, entry, learning, evolutionary, environment and endogenous timing games.

Part III provides an overview of some important classes of models dealing with informational issues in imperfectly competitive markets, as trading under asymmetric information, principal-agent under moral hazard, information-sharing in oligopoly, firm pricing in presence of consumer search and learning in markets.

Part IV aims at surveying both cooperative and noncooperative games commonly adopted for the analysis of horizontal mergers, firm collusion in vertically differentiated markets, leniency effects in cartels and coordinated effects in mergers.

Finally, part V presents a wide range of relevant applications of game theory to industrial organization as those of strategic delegation, liability and product safety, platforms and networks, auctions, intellectual property rights, healthcare market, corruption, all analyzed through rigorous game-theoretic settings. Last but not least, two excellent surveys dealing with the recent advances in experimental industrial organization and empirical models of firms' R&D conclude part V and the volume. In the next sections we enter in more detail in the content of all single chapter composing the *Handbook*.

1. PART I: BASIC GAMES IN INDUSTRIAL ORGANIZATION

In the chapter on *strategic complementarities in oligopoly* Xavier Vives provides a detailed overview of many recent results obtained by applying the techniques of supermodular games to the analysis of firm behaviour in imperfect competitive markets. Beside offering an excellent introduction to the recent lattice-theoretic methods, the chapter reviews the results obtained in the existence and comparative statics of Cournot, Bertrand, R&D, advertising, multidimensional and multimarket competition models. In addition, it introduces the use of supermodularity for the analysis of well-known classes of two-stage dynamic games as entry, dynamic strategic incentives and both Markov and incomplete information games applied to voluntary disclosures and auctions.

In the chapter on the *existence and comparative statics in Cournot and Bertrand oligopoly*, Rabah Amir surveys two important strands of literature in oligopoly theory, one dealing with the existence of Cournot equilibrium in the general asymmetric and symmetric cases and the other with the effects of exogenous entry on market performance in a Cournot industry. This chapter emphasizes that these two strands of literature share one important unifying common feature: both are achieved via the application of lattice-theoretic methods. This also provides a bridge with the previous chapter.

In *aggregative games* Martin Kaae Jensen nicely complements the first two chapters by introducing three important classes of widely used aggregative games: (i) linearly aggregative games; (ii) generalized aggregative games; (iii) quasi aggregative games. These games are very useful in industrial organization since they drastically simplify the analysis of existence, comparative statics and uniqueness of Nash equilibria and unify a vast amount of literature since they apply to a wide array of models like Cournot and Bertrand oligopoly, tournaments, work in teams, contests, patent races and network games.

In the following chapter *monopolistic competition with no apology*, Jacques Thisse and Philip Ushchev review what has been accomplished under the heading of monopolistic competition in industrial organization and in other closely related economic fields. Among other

things, the authors argue that monopolistic competition is a market structure in its own right which encompasses a much broader set-up than the celebrated constant elasticity of substitution (CES) model. Also, although oligopolistic and monopolistic competition compete for adherents within the economics profession, the authors explain how such dichotomy is, to a large extent, unwarranted, being both models complements rather than substitutes.

In *oligopoly and product differentiation* Jean Gabszewicz and Ornella Tarola overview old and new oligopoly models on product differentiation characterized by local competition. Starting by the microeconomic theory of consumer demand based on characteristics, as introduced by Gorman (1956 and 1980) and then popularized by Lancaster (1966), they present the horizontal product differentiation as based on Hotelling (1929) and vertical product differentiation as based on Gabszewicz and Thisse (1979). Finally, they review the model nesting both horizontal and vertical product differentiation and propose two applications of this approach, one based on network externalities and the other on environmental economics.

In his chapter on *oligopolistic competition and welfare*, Robert Ritz nicely reviews the recent developments in the study of social welfare in oligopoly markets. In particular, the chapter covers the usefulness of the rate of cost pass-through for the analysis of market performance and includes a careful analysis of welfare losses due to market power in various widely-used models (with symmetric and asymmetric firms, and with or without endogenous entry).

In the final chapter of part I, *Contest theory: a survey*, Luis Corchón and Marco Serena introduce the readers to the main ingredients of contests, with a focus on how the efforts of the agents translate into probabilities of winning (i.e., the contest success function). In the second part of the survey, they focus on some extensions of the basic model, with a particular interest on dynamics, information and groups. They use the popular lottery model of contest with heterogeneous contestants to highlight their equilibrium properties and to review some results on how a designer can optimally design the contest.

2. PART II: DYNAMIC GAMES IN INDUSTRIAL ORGANIZATION

This second part of the book offers a collection of chapters focussing on the use of dynamic games in a set of well known industrial organization issues.

The initial chapter by Klaus Ritzberger on *dynamic games* sets the ground by introducing three alternative definitions of game trees and extensive forms and also discussing in detail their pros and cons. In the following sections, the author comes back to the normal form associated to the extensive form and explains the concept of perfect recall and its significance for economic applications.

In *Strategic Refinements*, Carlos Pimienta examines the classical literature on equilibrium refinements. Starting with Nash's definition of equilibrium, the chapter presents a comprehensive review of the most successful equilibrium concepts adopted in economic applications as well as the most recent contributions to the subject. The chapter explains in detail how a few decision-theoretic criteria - admissibility, backwards induction, forward induction and invariance - shape the definition of stable sets of equilibria and how they translate into their corresponding mathematical formulation.

In *Stackelberg games* Ludovic Julien introduces three classes of deterministic noncooperative Stackelberg games with increasing level of generality. The first is the basic duopoly game. The second is the oligopoly multiple leader-follower game. The third extends the

multiple leader-follower setup within the framework of bilateral oligopoly to describe a multi-commodity market. In each case, the author defines and characterizes the equilibrium and the welfare consequences of market power. The chapter also considers the issues of endogenous timing, merging and free entry.

In the chapter on *entry games and free entry equilibria*, Michele Polo reviews the theoretical literature on these two fundamental topics. He shows how a wide range of symmetric oligopoly models share some common comparative statics properties. Individual profits and quantities decrease in the number of firms, and tend to competitive or monopolistic competitive equilibria when the number of firms increases indefinitely. The maximum number of firms sustainable in a symmetric long-run equilibrium are shown to depend on technology (economies of scale), preferences (market size) and strategies (toughness of price competition). On the normative side, in homogeneous product markets the business stealing effect drives the result of excessive entry, whereas adding product differentiation and the utility from variety may revert this result. In addition the author considers asymmetric free entry equilibria using the aggregative nature of many oligopoly models as we noted before. Finally, he discusses the issue of endogenous sunk costs, persistent concentration and frictionless entry in contestable markets.

In their chapter *Evolutionary oligopoly games with heterogeneous adaptive players*, Gian Italo Bischi, Fabio Lamantia and Davide Radi analyze the properties of evolutionary switching models in oligopoly games, where boundedly rational agents can follow different behavioral rules (or heuristics) to update their production through repeated adaptive decisions. In particular, they focus on well known heuristics such as best replies with naive expectations, local monopolistic approximation and gradient dynamics on marginal profits. Hence, the chapter examines some specific examples of evolutionary systems where the coexistence of heterogeneous behaviors and of oscillatory time patterns are obtained as possible outcomes.

In the chapter on *differential oligopoly games in environment and resource economics*, Luca Lambertini offers a comprehensive overview of the literature based on differential games whose main focus is the interplay between either regulated or unregulated oligopolistic firms' profit incentives and the preservation of the stock of natural capital. The first section introduces Cournot oligopoly games with either polluting emissions or resource extraction under open-loop rules, without regulation on emissions or access to the commons. The second section reviews the literature on environmental games with feedback structures, where firms may be subject to emission taxes and possibly activate R&D projects for green technologies. The third section considers games with exploitation of renewable and nonrenewable resources. The final sections are devoted, in turn, to the corporate environmentalism and to the Porter's assumption as well as to the issue of international trade and the environment, both crucial for the ongoing debate on globalization and climate change.

In the final chapter of part II, *endogenous timing in contests*, Magnus Hoffmann and Grégoire Rota-Graziosi survey the extensive literature on endogenous timing in contests. They firstly introduce the structure of a two-player contest with either simultaneous or sequential moves and fixed prizes. They then present the case of ubiquitous contests with effort-dependent prizes, in which timing is endogenously determined. Finally, they conclude by looking in detail at the literature on sequential play, endogenous timing, and commitment in contests.

3. PART III: INFORMATION AND SEARCH

This third part of the Handbook look at the effects on markets by relaxing the assumption of symmetric information.

In their chapter *trading under asymmetric information: positive and normative implications*, Andrea Attar and Claude d'Aspremont mainly focus their attention on screening models. They divide the chapter in two parts. The first part adopts a simple mechanism design approach with only one mechanism designer. When the mechanism designer is an outsider (say a public authority), all traders may have private information and play simultaneously. When the mechanism designer is an insider (a principal, buyer or seller), he is uninformed and has no private information. Three illustrative applications are taken into account: bilateral trade, auctions and insurance. In the second part of the chapter these model are extended to the case of several principals who are uninformed and have no private information but compete by designing mechanisms.

In *moral hazard: base models and two extensions*, Inés Macho-Stadler and David Pérez-Castrillo analyze first the optimal contracts in static moral hazard situations, where the agent's effort is not verifiable. Then, they present the main trade-offs of the principal-agent model. Furthermore, they treat in detail the trade-off of incentives (motivation) vs. risk-sharing (efficiency), incentives vs. rents (when the agent is protected by limited liability), incentives to a task vs. incentives to another (in a multitask situation), and incentives to the agent vs. incentives to the principal (when both exert a non-verifiable effort). Finally, they discuss how the predictions of the classical moral hazard model are affected when: (i) there are behavioral biases of individuals and, (ii) in presence of a matching market.

In their chapter *information sharing in oligopoly*, Sergio Currarini and Francesco Feri review the theoretical literature on information sharing in oligopoly and discuss some recent contributions extending the traditional multilateral model to encompass the possibility of bilateral sharing agreements. In the first part of the survey the authors revisit the early insights of the literature, stressing the role of quantity vs. price competition and of common vs. private values. In the second part, following some more recent contributions, they discuss the bilateral model of information sharing, stressing the role of signals' correlation for the emergence of information sharing in equilibrium and its effect on the architecture of sharing networks. Finally, they conclude the analysis by discussing the emergence of core-periphery networks when firms possess asymmetric information.

In *firm, pricing with consumer search*, Simon Anderson and Regis Renault discuss in detail the basic concepts underpinning the theory of imperfectly competitive markets with consumer search. They first stress how the appropriate theoretical frameworks should involve sufficient heterogeneity among agents on both sides of the market. Moreover, they explain why the analysis of ordered search constitutes an essential ingredient for modeling recent search environments. Finally, they examine in detail the important issue of the impact of the reduced search cost on prices, variety, product choice and advertising practices.

In the conclusive chapter of part III on *learning in markets*, Amparo Urbano surveys the problem of market learning as well as that of experimentation (or active market learning) in dynamic models incorporating a Bayesian expectation revision mechanism. Through the lens of this perspective, she reviews the extensive literature on this topic. The experimentation literature has by and large focused on broadly defined bandit models, and thus the starting point is the monopolist experimentation with the classic two-armed bandit problem. The

essay extends to surveying the impact of price competition on experimentation, the role of externalities in social learning and learning in experience good markets.

4. PART IV: COLLUSION AND MERGERS

In this part of the volume we gather a group of contributions on collusion and mergers in oligopolies. In the first chapter *coalitions and networks in oligopolies*, Francis Bloch reviews the models on endogenous formation of coalitions and networks in oligopolies. It weaves together a literature in game theory on cooperation and a literature in industrial organization on the formation of groups of oligopolistic firms. The discussion of cooperation in oligopolies starts with a brief presentation of the game-theoretic models used to predict the formation of coalitions and networks. Two different forms of cooperation are considered: (i) cartels and horizontal mergers; (ii) strategic alliances, which encompass both research joint ventures and information exchange platforms.

In the chapter on *TU oligopoly games and industrial cooperation*, Jingang Zhao surveys the existing results on TU cooperative games applied to oligopolies and lists nine promising future areas for TU oligopoly games. On the theoretical side, TU oligopoly games are shown to make advances on the refinements and applications of the core, one of the most important solution concepts in cooperative game theory. On the empirical side, the author shows how cooperative games can allow the analysis of industrial cooperation and, hence, the understanding of all forces at work behind industrial changes with and without regulatory policies.

In *horizontal mergers in oligopoly*, Ramon Faulí-Oller and Joel Sandonis analyze in turn the case of exogenous and endogenous mergers. In addition, the chapter examines in detail the models of horizontal mergers in vertically related industries and the models of mergers in an international setting, also looking at their welfare consequences.

In *collusive agreements in vertically differentiated markets*, Marco Marini introduces a number of game-theoretic tools which can be used to model the collusion between firms in a vertically differentiated market. The chapter starts reviewing the classical literature on two-firm collusion and then the analysis is extended to a n -firm vertically differentiated market to study the incentive to form either a whole market cartel or partial cartels made of subsets of firms colluding in prices. It is shown that a sufficient condition for the coalitional stability of the whole market cartel is the equidistance of firms' products along the quality spectrum. Also, adopting a standard infinitely repeated game approach, it is shown how an increase in the number of firms in the market may have contradictory effects on the incentive of firms to collude. Finally, by means of a three-firm example, it is studied the case of alliances with endogenous qualities.

In their chapter *cartels and leniency: taking stock of what we learnt*, Catarina Marvao and Giancarlo Spagnolo study leniency policies. These policies reduce or cancel the sanctions for the first firm(s) that self-report being part of a cartel. They have become the main enforcement instrument used by competition authorities to fight against cartels. Hence, it is vital for competition authorities to understand how leniency programs affect firms' incentives, in order to optimize their design and administration. In this chapter, the authors review some of the key studies which have been undertaken to date, with emphasis on more recent contributions and highlight the main results and their limitations. The chapter concludes

with a general assessment and an agenda for future research on this topic at the core of competition policy.

In the final chapter of part IV, *coordinated effects in mergers*, Natalia Fabra and Massimo Motta focus on the analysis of coordinated effects in merger cases, i.e., the possibility that, after a merger, firms can increase their market power by coordinating their actions. The authors explain what coordinated effects are and how they can be assessed. For this purpose, they review the economic meaning of collusion, and assess the factors that allow firms to reach and enforce collusive outcomes. They also review some approaches for identifying and quantifying coordinated effects in practice, and provide an overview of the use of coordinated effects in European merger control.

5. PART V: SPECIAL TOPICS

This last part of the *Handbook* is devoted to present wide array of applications of game theory to specific industrial organization topics.

In the first chapter *strategic delegation in oligopoly*, Michael Kopel and Mario Pezzino provide the reader with a clear and intuitive description of the topic of strategic managerial incentives under oligopolistic competition. They describe in detail the related models of vertical separation, where a manufacturer delegates her decisions to a retailer, and the agent appointment game, where a principal delegates her decisions to a certain type of agent. Each of these themes is presented by discussing the seminal paper that has first introduced the topic, its key assumptions and its applications along with some empirical and experimental evidence. The contributions that have provided important extensions to the basic frameworks are also discussed in a final section of the chapter.

In *market structure, liability, and product safety*, Andrew Daughety and Jennifer Reinganum consider how models of imperfect competition provide insight into an important area of law: products liability, which is liability for harms and losses associated with goods and services sold via markets. Traditional law and economics analyses of products liability generally find no role for market structure or strategic interaction to influence safety or liability policy. Rather, different liability regimes, and alternative market structures, lead to the same private choice of safety, and this private choice is socially optimal. Daughety and Reinganum find that two simple (but plausible) model modifications, cumulative harm or endogenous fixed costs, yield a substantial impact of market structure on the choice of safety and liability regime.

In the chapter *platforms and network effects*, Paul Belleflamme and Martin Peitz review the key findings of the literature on network effects and two-sided platforms. They explore how to define network effects and markets with platforms, and investigate market demand and the provision of network goods. Then they lay out the basic models of monopoly platforms and platform competition, and elaborate on some routes taken by recent research.

In the chapter on *auctions*, Angel Hernando-Veciana provides an overview of the advances in the auction field that have taken place in the last decade. To this aim, the survey starts with an introductory section in which the basic tools of analysis are summarized. Next, the main advances occurred in three innovative areas of auction theory are spelled out in detail: position auctions, internet auctions and combinatorial auctions. The final section of the chapter summarizes the major contributions to auction theory organized by topics.

In *Intellectual property*, Miguel González-Maestre discusses the current literature on intellectual property right from a perspective taking into account two main features of the evolution of modern economies: (i) the increasing level of complexity associated with the production and design of goods, and (ii) the rapid development of new technologies of information and communication. To this end, the chapter mainly focusses on the recent literature dealing with the role of technological changes on the optimal design of patents and copyrights. This overview suggests that the substantial changes observed in Western economies, aiming at reinforcing intellectual property rights, cannot be justified neither theoretically nor empirically on the grounds of welfare or of creative and innovational incentives. Instead, alternative explanations based on rent-seeking and lobbying activities by copyright or patent holders emerge as their most plausible rationale.

In his chapter on *healthcare and health insurance markets*, Pau Olivella introduces some modelling tools for the analysis of healthcare provision and health insurance. In particular, the chapter devotes great attention to a series of topics for which the tools of industrial organization and game theory have proven most fruitful: (i) firms' incentives to invest in R&D in the pharmaceutical industry; (ii) risk selection and screening of consumers; (iii) the effect of hospitals' competition.

In the *microeconomics of corruption. A review of thirty years of research*, Roberto Burguet, Juan José Ganuza and José García Montalvo review the most recent research on corruption. They start by analyzing the seminal models of corruption built on three-tier delegation models. Then, they discuss the case of corrupted deals to see which main economic factors affect corruption. Incentives and compensations in bureaucracies, as well as the strict interplay of market and bureaucracies are discussed. Competition and contract design are also reviewed in relation to procurement in presence of corruptible agents. After reviewing theory, the authors turn to empirical evidence. Finally, they critically evaluate several anti-corruption mechanisms proposed by the literature to both control and eliminate illegal activities.

In the chapter on *experimental industrial organization*, Jordi Brandts and Jan Potters present a selective survey of the recent experimental studies on industrial organization issues. The first section of the chapter presents, starting with the classical models of Cournot, Bertrand and Stackelberg, the results of experiments based on static models involving the choices of quantities and prices. The second section deals with tacit collusion. The third section covers horizontal product differentiation and the fourth discusses experience and credence goods. The last section presents a few studies on entry deterrence and R&D competition.

In the conclusive chapter *empirical models of firms' R&D*, Andres Barge, Elena Huergo, Alberto López and Lourdes Moreno survey the ever growing empirical literature of R&D. This literature is still growing just because of the increasing availability of micro-data. Taking this fact into account, the main purpose of this chapter is to provide an overview of three important topics covered by the literature: the determinants of firms' R&D investment, the link between R&D, innovation and productivity, the analysis of the *R&D black box*. This chapter is presented as an invitation to IO practitioners, both theorists and applied, to cross the bridge (and change sides) between theory and applications.

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